Assessment/Development/Validation of Computational Fracture Mechanics Methodologies and Tools for Shot-Peened Materials Used in Rotorcraft Principal Structural Elements

S. Shen and S.N. Atluri
Center for Aerospace Research & Education
University of California at Irvine

Abstract:

The physics of the shot-peening process is fairly well understood: 1. The impact of a large number of shot onto the surface of a structural element causes residual plasticity near the surface; 2. This induces a localized compressive stress field in directions normal to the depth-direction near the surface; and 3. These compressive residual stresses reduce the likelihood of surface cracks and retard their subsequent growth under fatigue loading; thus having a positive effect on the damage-tolerant life of the structure. The present research is aimed at 1. Theoretically predicting the state of the material after shot peening, without having rely on extensive testing; 2. To design appropriate shot-peening processes that would achieve the desired results in terms of residual stress-fields; and 3. To examine the effects of shot-peening the material under subsequent fatigue loading.

The main parametric variations in a shot-peening process are 1. Material properties of the shot, such as, grade, shape and hardness of the shot, and the fraction of the broken shot; 2. Peening parameters, such as the velocity of the shot, nozzle diameter, mass-flow rate, peening-time and impact angle; and 3. Intensity and coverage of the surface that is shot-peened. To simply attempt a totally numerical-based analysis of all these parameters is impractical and unfeasible.

The ambitious goal of this research is to develop a theoretically sound analytical/mathematical analysis of the residual stress-field near the surface of an ***elastic-strain-hardening plastic solid*** that is shot-peened. The theoretical model will encompass all the shot-peening parameters mentioned above. The paper and the talk will present the details of such an analytical model. Such a model, for the first time, will enable the assessment of the effects of shot peening, with all its parametric variations, on the primary structural elements in rotorcraft.

The currently developed analytical model for shot-peening is being embedded in AGILE (Automated Global/Intermediate/Local Analysis), which uses the Symmetric-Galerkin Boundary-Element Method/ Finite-Element-Alternating-Method for the prediction of ***non-planar fatigue-crack growth*** in an arbitrarily loaded primary structural element in a rotorcraft. Thus, in performing a damage-tolerance/life-estimation/residual-strength analysis, AGILE can easily quantify the effects of shot-peening, with all its parametric variations, on the subsequent fatigue-growth retardation of surface cracks in rotorcraft structural components.

The theoretical developments will also be validated, using the independent test-data generated in a companion experimental program at the University of Washington.